

DECONTAMINATION OF RADIONUCLIDE CONTAMINATED SURFACES USING ABRASIVE REMOVAL TECHNIQUES (SCABBLING)

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ABSTRACT

This paper will both summarize the regulatory requirements (e.g.: NRC, EPA, state) surrounding radiological decontamination of porous surfaces using abrasive removal techniques (scabbling), and present a mathematical model used for estimation of particulate dust emissions during scabbling activities. A case study example of decontamination for free release employed at a Fortune 500 Facility to meet NRC Release for Unrestricted Use Standards will also be discussed.

INTRODUCTION

As most commercially licensed facilities near the end of their useful design lives, facility owners undertaking decommissioning activities are faced with the now Herculean task of safely and cost effectively decontaminating, and in most cases, dismantling these facilities. To achieve this task, cost effective methods are being sought to decontaminate structures and coincidentally reduce the volume of radioactively contaminated wastes destined for burial. As there are currently few commercial land disposal facilities licensed to accept radioactivity in the U.S., one finds that the cost of radioactive waste disposal can easily eat up those accumulated decommissioning escrow funds collected over the facility's operating life.

In order to minimize the radioactive waste disposal costs, many decommissioning sites attempt to eradicate surface radionuclide contamination from base construction materials wherever possible and thereby reduce the volume of redwaste being earmarked for burial. One type of popular decontamination method being employed is scabbling, an abrasive surface layer removal technique. This method of decontamination is typically used to remove the uppermost radioactively contaminated surface layers of concrete structural members. When completed, one is left with two resulting wastestreams: (1) the highly contaminated dust removed during scabbling, and (2) the resulting "clean" base structure. By removing this contaminated layer, one can typically survey the base portions "clean" in order to obtain release for unrestricted use for the high volume base structure allowing for either its reuse in commerce or land disposal at a demolition debris landfill.

In order to perform this type of remediation activity, one must be aware that there are numerous regulatory hurdles set forth by the Nuclear Regulatory Commission (NRC) as well as the Environmental Protection Agency (EPA) that one must carefully plan for and contend with during decommissioning. These include methods for surveying, licensing strategies, management of both removed scabble dust and the base structural materials, and permitting for the resulting air emissions generated including calculation and

modeling of contaminants. This paper will begin with a summary background description of the NRC's Decommissioning regulations, an outline of the Clean Air Act and NRC regulatory requirements for air emissions, a description of methods for estimation of air emissions generated during scabbling operations, and a case study of scabble air emissions estimating at a Fortune 500 Company facility undergoing decommissioning.

SUMMARY OF NRC DECOMMISSIONING REGULATIONS

In order to terminate a license and release a site, a licensee must demonstrate that the site is suitable for release in accordance with the criteria for decommissioning in Subpart E, "Radiological Criteria for License Termination," of 10 CFR Part 20. These requirements were published as a final regulation on July 21, 1997 (62 FR 39058).

The new rule allows for termination of a license and release for unrestricted use if the following criteria are met. First, the residual radioactivity above background results in a dose to the average member of the critical group that does not exceed 25 mrem/yr (0.25 mSv/yr). Second, the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). The new rule also allows for termination of a license and release for restricted use if other specified conditions are met.

Under each type of license termination, a dose assessment is performed to determine the levels of residual radioactivity which meet the dose constraints. NRC guidance on dose assessment is provided in Draft Regulatory Guide 4006, "Demonstrating Compliance with the Radiological Criteria for License Termination" and Draft NUREG -1549, "Using Decision Methods for Dose Assessment to Comply with Radiological Criteria for License Termination." Utilizing the new rule and guidance, the licensee derives release criteria for soil and bulk material in pCi/g and release criteria for building surfaces (dpm/100 cm²).

After the release criteria is determined, remediation is performed on the areas of the site that are in excess of the criteria. This may include removal of soils, washing of building surfaces, or scabbling.

Following remediation, a final status survey must be performed to demonstrate that the area meets the radiological release criteria. The NRC endorses the final status survey method described in NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)." The MARSSIM provides information on planning, conducting, evaluating, and documenting surface soil and building surface final status radiological surveys for demonstrating compliance with dose or risk-based regulations or standards.

After the final status survey has been completed, the licensee submits the final status survey report to the NRC for approval and license termination.

AIR EMISSION REGULATIONS AND PERMITTING

In order to achieve the above NRC release for unrestricted use and license termination benchmarks, many facilities have opted to decontaminate site structures utilizing the scabbling process to remove the usually highly contaminated surface layers and release for unrestricted use the base material. An inherent by product of the scabbling process is the generation of relatively large quantities of fine dust particles. These dust particles, given their low mass, quite easily become airborne at the slightest disturbance. Hence, in order to protect the health of the workers, an effective means of collecting these dust particles must be an intricate part of any scabbling scheme. Because this airborne dust is also quite radioactive, extreme care must be taken to prevent any uncontrolled releases from the worksite to further protect human health and the environment.

In order to prevent the uncontrolled release of radioactive dust from scabbling activities, practically all scabbling must be performed in a negative pressure enclosure with exhaust air being appropriately filtered to remove the dust prior to discharge from the workspace. These controlled airborne exhaust streams typically exit the workspace through either point sources (stacks) or as fugitive emissions.

Certain airborne contaminants which enter the environment are currently regulated as conventional or "criteria" air pollutants by EPA. As a result of scabbling activities, many types of airborne contaminants have the potential to be generated and discharged into the environment. Conventional airborne contaminants generated during scabbling are typically limited to PM₁₀ (described below).

Radionuclides, lead, cadmium, chromium, or Polychlorinated Biphenyls (PCB's) may also be generated, typically resulting from scabbling of painted or coated surfaces which originally contained these compounds as ingredients. EPA classifies these types of contaminants as Hazardous Air Pollutants (HAP's). A total of 189 HAP's have been identified by statute and are listed in Section 112 of the Clean Air Act.

PM₁₀

PM₁₀ is essentially defined by EPA at 40 CFR 50.6 as "...particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers...". EPA regulation of PM₁₀ as an air contaminant derives from the establishment of National Ambient Air Quality Standards (NAAQS) in the Clean Air Act (CAA). Originally signed into law in 1970, the CAA established NAAQS for 6 ambient air criteria pollutants. These pollutants are Sulfur Oxides, Carbon Oxides, Nitrogen Oxides, Ozone, Lead, and Particulate Matter (e.g. PM₁₀). For each of the pollutants, EPA established an ambient air concentration (NAAQS) designed to be protective of human health and the environment.

In order to regulate these criteria pollutants, EPA required that each state develop and submit to EPA a State Implementation Plan (SIP) detailing the methods whereby it will ensure that all areas in their respective states meet the NAAQS. If any one area exceeds the NAAQS, it is deemed in non-attainment status and the SIP must identify method(s) describing how the area will be brought into attainment status with the NAAQS.

The most often used method developed by states to comply with the NAAQS provisions has been to establish a permitting system for all air contaminant sources. These permits are used to regulate and reduce the amounts of criteria pollutants emitted from both point and fugitive sources. Note that the Title V permitting regimen is a fairly recent product of the CAA Amendments of 1990 where the old SIP operating permit system harkens from the SIP's submitted as a result of the original CAA provisions of 1970.

As most states require air quality permits for criteria pollutant emissions, when performing scabbling operations, one is typically required to obtain operating permits for the resulting dust emissions generated during scabbling operations. These permit applications often require that the facility estimate the quantities of pollutants emitted and, accordingly, employ the necessary controls to ensure that these emissions do not result in exceedences of the NAAQS in the specific work area.

As stated above, other pollutants (HAP's such as chromium, cadmium, lead, PCB's) may also be entrained in the dust if a painted coating originally containing any of these materials is also removed during scabbling. The chromium, cadmium, and PCB are classified by EPA as toxic air pollutants and control of these pollutants are covered under EPA's air toxics provisions (discussed below).

AIR TOXICS & NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS

Through the CAA of 1970 EPA was delegated the responsibility of developing, listing, and regulating those air contaminants demonstrated to be harmful to both human health and the environment. Prior to the CAAA of 1990, EPA worked on a chemical-by-chemical basis to identify and list those toxic air contaminants or HAP's (as opposed to criteria contaminants) known to be risks to health. In the time span between the CAA of 1970 and the CAAA of 1990, EPA had listed only seven chemicals known to be hazardous to human health and the environment, namely, asbestos, benzene, beryllium, arsenic, mercury, radionuclides, and vinyl chloride. EPA then promulgated "National Emission Standard for Hazardous Air Pollutants" (NESHAPS) for each HAP identified. These NESHAPS outlined the control methods required for sources of HAP emissions.

Given that only seven HAP's were identified by EPA in an almost 20 year time span, Congress in the CAAA of 1990, modified its HAP approach to one that regulates by industry rather by chemical health risks, and is technology and performance based rather than health based. Accordingly, Congress generated a list of 189 HAP's (listed in Section 112 of the CAA) believed to cause adverse health or environmental risks to be regulated by EPA over an approximate 10 year time span. EPA is presently in the process for developing NESHAPS for these industrial source categories and their HAP emissions. This new list of 189 HAP's includes chromium, cadmium, and lead compounds in addition to PCB's and *radionuclides*.

In actuality, many states began to regulate HAP's as part of their SIP's long before the CAAA of 1990. Therefore, even if one is not a major source of HAP's, your state may already require permitting under the state's SIP for sources that generate appreciable

quantities of certain HAP's. An example is Pennsylvania where sources that emit settled particulates, beryllium, sulfates, fluorides, or hydrogen sulfides must be permitted under the state's SIP permitting system since these have been identified as criteria pollutants in addition to those 6 previously identified by the CAA of 1970.

EPA REGULATION OF RADIONUCLIDES

As stated previously, EPA had identified radionuclides as contaminants which could pose a risk of hazards to both human health and the environment. Hence, NESHAPS for radionuclides were developed and codified at 40 CFR 61, Subparts H and I. Subpart H provisions "NATIONAL EMISSION STANDARDS FOR EMISSIONS OF RADIONUCLIDES OTHER THAN RADON FROM DEPARTMENT OF ENERGY FACILITIES" apply at DOE facilities. The Subpart I provisions "NATIONAL EMISSION STANDARDS FOR RADIONUCLIDE EMISSIONS FROM FEDERAL FACILITIES OTHER THAN NUCLEAR REGULATORY COMMISSION LICENSEES AND NOT COVERED BY SUBPART H"

The Subpart I provisions were originally promulgated on December 15, 1989 (54 FR 51654). Subpart I originally regulated air emissions from NRC licensed facilities and those not covered by then Subpart H. The only NRC licensed facilities not originally covered by the Subpart I provisions were commercial nuclear power reactors. Those NRC licensed facilities were the subject of a later rulemaking promulgated on September 5, 1995 (60 FR 46206).

Subpart I essentially required limited radionuclide emissions to the ambient air from NRC licensed facilities (other than nuclear power reactors) to that amount which would cause any member of the public to receive in any one year an effective dose equivalent of no greater than 10 millirem with no greater than 3 millirem from radioiodine. These facilities were required to estimate doses to exposed individuals using conventional approved air modeling and dose estimating methods. Most regulated entities demonstrated compliance with the Standard utilizing EPA's COMPLY computerized air modeling dose estimating software.

On December 30, 1996 (61 FR 68972) EPA published a Final Rule amending the applicability of Subpart I to the regulated community. The Final Rule rescinded the Subpart I requirements as it applied to NRC licensed facilities (other than power reactors). EPA rescinded applicability of its requirements in response to a determination that the NRC radionuclide air emission program for licensed facilities (other than power reactors) is sufficiently protective of public safety by an ample margin. Hence, those facilities originally regulated by the Subpart I provisions prior to the December 1996 Final Rule must now comply with the NRC's equivalent regulatory program. These programmatic requirements are further described below.

NRC REGULATION OF RADIONUCLIDES

In December of 1996, EPA rescinded 40 CFR Part 61, subpart I as it applied to NRC licensed facilities other than commercial nuclear power reactors (61 FR 68972). EPA determined that the NRC emission standards in 10 CFR Part 20 resulted in doses less

than the level found by EPA to provide an ample margin of safety to protect the public health. 10 CFR Part 20 requires that each licensee conduct operations so that the total effective dose equivalent to members of the public does not exceed 100 mrem in a year (1 mSv). Further, the NRC requires the licensee to implement ALARA requirements which includes a constraint on air emissions of radioactive material to the environment such that the total effective dose equivalent to members of the public does not exceed 10 mrem per year (0.1 mSv) from emissions.

The licensee must show compliance with the annual dose limit utilizing one of two methods. The first method is to demonstrate by measurement or calculation that the total effective dose equivalent to the maximally exposed individual does not exceed the annual dose limit. The second method is to demonstrate that the average concentrations of gaseous and liquid effluents at the boundary do not exceed the values specified in table 2 of appendix B to part 20. In addition, the licensee must demonstrate that if an individual were continuously present at the boundary, the dose from external sources would not exceed 2 mrem (0.02 mSv) in an hour and 50 mrem (0.5 mSv) in a year.

The NRC provides guidance on methods acceptable for demonstrating compliance in Regulatory Guide 4.20, "Constraint on Releases of Airborne Radioactive Materials to the Environment for Licensees Other Than Power Reactors." Reg Guide 4.20 describes four methods for demonstrating compliance.

The first method is the simplest screening technique. The licensee should assume that the air concentration at the receptor is equal to the air concentration at the point of release. Then, calculate the dose to the receptor.

The second method is to demonstrate, by measurement or calculation, that the annual average concentration released to the environment does not exceed 20% of the values in Column 1 of Table 2 in Appendix B to 10 CFR 20. The "sum of the fractions" technique should be for effluents containing multiple radionuclides.

The third method is to utilize guidance contained in either NCRP Commentary No. 3, "Screening Techniques for Determining Compliance with Environmental Standards," or EPA 520/1-89-002, "A Guide for Determining Compliance with the Clean Air Act Standards for Radionuclide Emissions from NRC-Licensed and Non-DOE Federal Facilities (Revision 2)."

The final method is the use of the computer code COMPLY. COMPLY was developed by EPA to assess doses by using site-specific information in the determination of dose. The use of the code is further discussed below.

If the constraint of 10 mrem (0.1 mSv) per year has been exceeded, the licensee must notify the NRC within 30 days after learning of the dose in excess of the constraint. The licensee must describe the extent of the exposure and prepare a report which includes information such as corrective actions.

AIR CONTAMINANT EMISSIONS ESTIMATING

As discussed above, emissions generated during scabbling activities may be regulated by the EPA, NRC, or an authorized state regulatory agency either separately or simultaneously. These regulatory requirements likely require permitting of the source under the facility's state SIP operating permit system, and adherence to the NRC's REGGUIDE. In both instances, quantification of the air emissions is required in order to properly complete the necessary dose or air modeling application sections.

In most instances, scabbling activities must be performed in an enclosed workspace under negative pressure. This is necessary to prevent the uncontrolled release of radionuclides or other air contaminants into the environment. A simplified schematic of a typical ventilated enclosure with air balance inputs and exhaust points is shown in **Figure 1**.

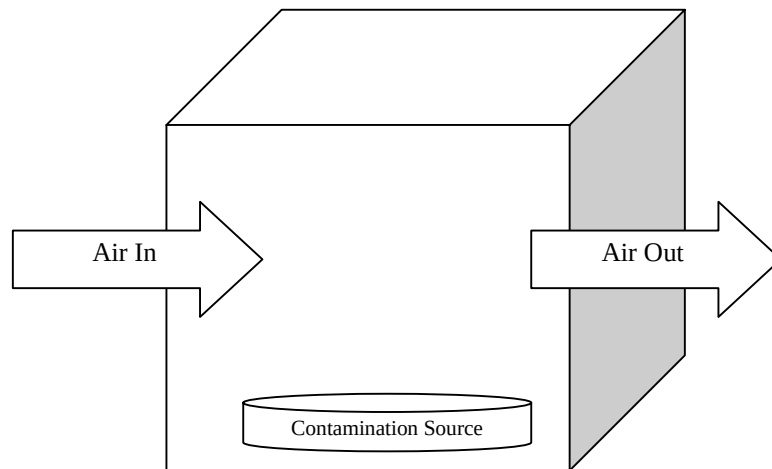


Figure 1 – Air Balance of Typical Ventilated Space

The controls necessary in the exhaust airstream must be sufficiently effective in removing subject air contaminants to environmentally acceptable levels. In most instances, this involves installation of High Efficiency Particulate Air (HEPA) filters to control radionuclides in the particulate laden exhaust air. Given that HEPA filtration generally is effective in removing 99.97% of particles with an aerodynamic diameter of 10 microns or less, this reduction, while substantially effective in removing radionuclide contamination, is also simultaneously extremely effective in removing PM₁₀ emissions in the exhaust air. Hence, provided the air contaminants of concern generated during scabbling consist of mainly PM₁₀ and radionuclides (with no fumes or vapors from surface coatings present), HEPA filtration typically represents the maximum achievable control technology for the contaminants being emitted.

A point to remember. Although HEPA filtration is extremely efficient in removing air contaminants such as PM_{10} and radionuclides, it is not 100% efficient. Hence, although seemingly insignificant, these de minimus emissions are still likely subject to permitting requirements under a state's SIP and also subject to NRC's radionuclide emission standards described above.

MODEL DERIVATION

In order to mathematically estimate the emissions from scabbling operations, the following initial simplifying assumptions may be made:

- Tight room with no fugitive emissions (i.e.: no inputs or releases from cracks)
- Airflow in = Airflow out
- Complete mix condition for dust in the room
- Principle contaminant of concern is PM_{10}
- Stack emissions are negligible during quiescent conditions

The following steps describe the derivation of a model for emissions estimating.

Step 1: Perform mass balance on room.

Figure 2 shows the parameters needed to simulate room conditions during scabbling.

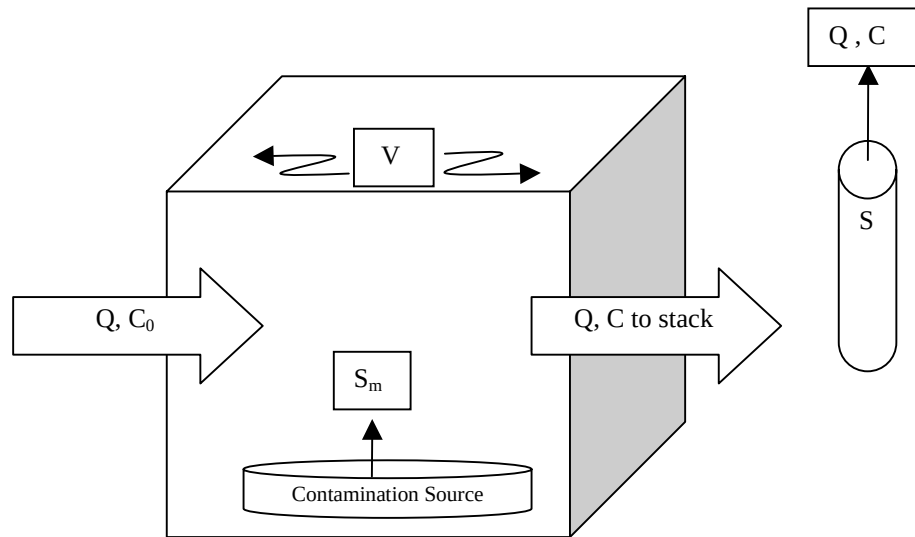


Figure 2 - Air Balance of Typical Ventilated Space with Variables Assigned

Where:

Q = Air Flowrate

C_0 = Influent PM_{10} Air Concentration

C = Room/Effluent PM_{10} Air Concentration

S_m = Emission Rate of Concrete Dust generated during scabbling

V = Room Volume

By performing a mass balance on the room, the following relationships can be established:

$$Accumulation = In - Out \quad \text{Eq. 1}$$

$$Accumulation = Mass\ Dust = CV \quad \text{Eq. 2}$$

Then, by assuming that the room is well mixed the following relationship can be established:

$$Room\ C = Effluent\ C \quad \text{Eq. 3}$$

Therefore,

$$In = (QC_0 + S_m)\Delta t \quad \text{Eq. 4}$$

$$Out = QC\Delta t \quad \text{Eq. 5}$$

where Δt = change in time.

Step 2: Substitute Equation 2, 4 and 5 into Equation 1 and solve for $\frac{CV}{\Delta t}$:

$$CV = (QC_0 + S_m)\Delta t - QC\Delta t \quad \text{Eq. 6}$$

$$\frac{CV}{\Delta t} = (QC_0 + S_m) - QC \quad \text{Eq. 7}$$

Step 3: Take the limit of Equation 7 as $\Delta t \rightarrow 0$:

$$\frac{dCV}{dt} = QC_0 + S_m - QC \quad \text{Eq. 8}$$

Step 4: Assume $C_0 = 0$ since there is no PM_{10} in the make-up air and divide Equation 8 by V and rewrite:

$$\frac{dC}{dt} = \frac{S_m}{V} - \frac{QC}{V} \quad \text{Eq. 9}$$

Then, by substituting $a = \frac{S_m}{V}$ and $b = -\frac{Q}{V}$ Equation 9 becomes:

$$\frac{dC}{dt} = a + bC \quad \text{Eq. 10}$$

Step 5: Solution to this differential equation is shown in Equation 11:

$$C(t) = C_0 e^{bt} - \frac{a}{b}(1 - e^{bt}) \quad \text{Eq. 11}$$

Substituting $C_0=0$ into Equation 11 yields:

$$C(t) = -\frac{a}{b}(1 - e^{bt}) \quad \text{Eq. 12}$$

Step 6: Substitute the values for a and b into Equation 12 and simplify:

$$C(t) = \frac{\frac{S_m}{V}}{\frac{Q}{V}}(1 - e^{-\frac{Q}{V}t}) \quad \text{Eq. 13}$$

$$C(t) = \frac{S_m}{Q}(1 - e^{-\frac{Q}{V}t}) \quad \text{Eq. 14}$$

Step 7: Note that $e^{-\frac{Q}{V}t}$ rapidly approaches 0 as t increases and reduce Equation 14 to:

$$C(t) = \frac{S_m}{Q} \quad \text{Eq. 15}$$

The conclusion is made that by knowing the emission rate of concrete dust during scabbling (S_m) and the ventilation flowrate (Q), one can calculate the effluent concentration in the room and the stack using Equation 15.

USE OF COMPLY TO CALCULATE DOSE TO NEAREST RECEPTOR

Once the effluent concentration, $C(t)$, is known, various air emission models can be used to estimate the fence line concentrations. One model, EPA's COMPLY computer code, was developed to assess doses by using site-specific information. COMPLY has four screening levels. In Level 1, the simplest level, only the quantity of radioactive material possessed during the monitoring period and release rates are entered. The calculations

are then performed using generic parameters. Levels 2 through 4 required increasing amounts of site-specific data to perform the calculations. The site-specific data includes such information as release height, building height, volumetric flow rate, wind speed, ambient air temperature, and wind rose. The licensee may start at any level; however, it is recommended to begin at the lowest level.

The output of the computer code consists of tables indicating which screening level was utilized, which input parameters were used, and the results. The results give the effective dose equivalent due to all radionuclides and the effective dose equivalent due to iodine (if necessary). The code then compares these doses to the limits and determines compliance.

CASE STUDY

Recently a Fortune 500 Company's licensed facility was undergoing decontamination while being decommissioned. Surface activity was found inside the facility and the decision was made to decontaminate to the greatest extent possible the contaminated surfaces thereby allowing for release for unrestricted use of the building.

The strategy envisioned was to use the existing ventilation system to control radionuclides and particulate matter generated during scabbling decontamination activities. The building's ventilation system had been previously optimized for radionuclide removal to support then production operations. Each of the 6 existing ventilation units (F-1, F-6, F-7, F-9, F-10, F-11) was previously equipped with a series of both pre-filters (roughing filters) followed by a single stage of downstream HEPA filtration. Hence, little construction costs would be required for upgrading of the ventilation system to support scabbling operations.

In order to properly estimate the worst case emissions using the above model (Equation 15), some simplifying assumptions were required:

- Scabbling operations would occur in only one section of the facility at any one time;
- Air balancing within the building would be such that scabbling emissions would be discharged through only one of the ventilation units at any one time;

Calculation of actual PM_{10} emissions during scabbling were performed as follows.

The PM_{10} emission rate, S_m , of the dust generated during scabbling must first be established based on the following assumptions. The scabbling operations will occur both at grade (floor level) and at various elevations (walls and ceilings). From direct measurement of previous scabbling operations, the concrete dust generation rates, S_m , were determined to be:

- 27.5 pounds of concrete dust per hour liberated for walls and ceilings, and
- 36.0 pounds of concrete dust per hour liberated for floors.

From publication EPA 450/4-90-003, "AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants," (1) Emission Factor 3-11-002-04 relating to Construction: Demolition of Structures, the PM_{10} emissions are given as 0.058 pounds PM_{10} per ton of waste material.

For the **walls and ceilings**, the PM_{10} emission rate ($S_{m-w/c}$) is:

$$S_{m-w/c} = \left(\frac{0.058 \text{ lbs } PM_{10}}{\text{ton concrete generated}} \right) \left(\frac{27.5 \text{ lbs concrete generated}}{\text{hr}} \right) \left(\frac{1 \text{ ton}}{2000 \text{ lbs}} \right)$$

$$S_{m-w/c} = 0.00080 \text{ lbs } PM_{10} / \text{hr} .$$

Likewise, for the **floors**, the PM_{10} emission rate (S_{m-f}) is:

$$S_{m-f} = \left(\frac{0.058 \text{ lbs } PM_{10}}{\text{ton concrete generated}} \right) \left(\frac{36.0 \text{ lbs concrete generated}}{\text{hr}} \right) \left(\frac{1 \text{ ton}}{2000 \text{ lbs}} \right)$$

$$S_{m-f} = 0.0010 \text{ lbs } PM_{10} / \text{hr}$$

Therefore, assuming that only one wall scabbler and one floor scabbler will be in service at any one time in each room, the worst case generation rate is the sum of the two. The total emission rate is therefore:

$$S_{m-total} = S_{m-w/c} + S_{m-f} = (0.00080 + 0.0010) \text{ lbs } PM_{10} / \text{hr}$$

$$S_{m-total} = 0.0018 \text{ lbs } PM_{10} / \text{hr}$$

Now, the worst case value for PM_{10} ($S_{m-total}$) may be substituted into Equation 15 yielding the following relationship for concrete dust generated during scabbling:

$$C = \frac{S_{m-total}}{Q}$$

$$C = \frac{0.0018 \text{ lbs } PM_{10} / \text{hr}}{Q} \quad \text{Eq. 16}$$

Table 1 lists the various ventilation units and their associated nominal flowrates. Each room in the building undergoing scabbling is serviced by a dedicated ventilation system designated F-# in **Table 1**. In addition, the corresponding room PM_{10} concentrations were calculated using Equation 16. For example, for F-6,

$$\text{Flowrate} = 6400 \text{ ft}^3/\text{min}$$

$$S_{m-total} = 0.0018 \text{ lbs } PM_{10}/\text{hr}$$

$$C_{F-6} = \frac{\left(\frac{0.0018 \text{ lbs } PM_{10}}{\text{hr}} \right) \left(\frac{453.6 \text{ g}}{\text{lb}} \right) \left(\frac{\text{hr}}{60 \text{ min}} \right)}{\frac{6400 \text{ ft}^3}{\text{min}}}$$

$$C_{F-6} = 2.13 \times 10^{-6} \text{ g} / \text{ft}^3$$

Table 1			
Room PM ₁₀ Concentrations			
Stack Designation	Nominal Flowrate (CFM)	Concrete Dust Generation Rate (S _{m-total}) (lbs PM ₁₀ /hr)	Room PM ₁₀ Concentration (g PM ₁₀ /ft ³)
F-1	15,600	0.0018	8.72E-07
F-6	6,400	0.0018	2.13E-06
F-7	4,000	0.0018	3.40E-06
F-9	4,300	0.0018	3.16E-06
F-10	4,500	0.0018	3.02E-06
F-11	4,800	0.0018	2.84E-06

The control measures to be performed include either single or multi-stage filtration through HEPA filters. Per "Industrial Ventilation" 20th Edition (ACGIH) (2), the HEPA efficiency of particulate removal using the dioctylphthalate (DOP) test on 0.3 micron particulates of DOP is 99.97%. This corresponds to a transmissivity of 1-.9997 or 0.03%. Based on our model, the stack effluent concentrations are identical to the room concentrations since it was assumed the room air was well mixed.

The general formula for the effluent concentrations may be obtained from the following formula:

$$C_{Stack} = C_{Room} * (Filter Transmissivity)^n \quad \text{Eq. 17}$$

where n is the number of stages of HEPA filtration.

Therefore, the following calculation can be made for the previous example. For the room serviced by stack F-6, the PM₁₀ concentration was 2.13E-06 g/ft³. The effluent concentration is then determined using Equation 17:

$$C_{Stack-F-6} = C_{Room-F-6} * (Filter Transmissivity)^n$$

There is one stage of HEPA filtration therefore, n=1.

$$C_{Stack-F-6} = (2.13 \text{ E} - 06 \text{ g} / \text{ft}^3)(0.003)^1$$

$$C_{Stack-F-6} = 6.38E-10 \text{ g PM}_{10} / \text{ft}^3$$

Table 2 shows the results Stack Effluent PM₁₀ for all stacks.

Table 2 Stack Effluent PM ₁₀ Concentrations						
Stack Designation	Nominal Flowrate (CFM)	Concrete Dust Generation Rate (lbs PM ₁₀ /hr)	Room PM ₁₀ Conc (g PM ₁₀ /ft ³)	HEPA Filter Transmissivity (0.03%)	Number of HEPA Stages	Stack Effluent PM ₁₀ Conc (g PM ₁₀ /ft ³)
F-1	15,600	0.00018	8.72E-07	0.0003	1	2.62E-10
F-6	6,400	0.00018	2.13E-06	0.0003	1	6.38E-10
F-7	4,000	0.00018	3.40E-06	0.0003	1	1.02E-09
F-9	4,300	0.00018	3.16E-06	0.0003	1	9.49E-10
F-10	4,500	0.00018	3.02E-06	0.0003	1	9.07E-10
F-11	4,800	0.00018	2.84E-06	0.0003	1	8.51E-10

As can be seen, as the CFM for each unit increases, the room PM₁₀ concentrations decrease. This follows since in Eq. 16, if $S_{m-total}$ is constant, and Q increases, then C must decrease. The above maximum emissions (namely F-7) were then entered on the air quality permit application accordingly as it was assumed only one ventilation unit would discharge scabbling emissions at any one time. Note that since HEPA filtration controls are 99.97% efficient for PM₁₀, the PM₁₀ emissions are practically non-existent. Hence, the need for HEPA filtration to control radionuclides has the added simultaneous benefit of practically eliminating the PM₁₀ emissions.

CONCLUSIONS

By using scabbling as a method for achieving release for unrestricted use of radioactively contaminated structures, one may effectively minimize the volume of radioactive waste generated resulting in lower decommissioning costs. Although air emissions will almost always be generated during these scabbling operations, the controls necessary for reducing radionuclide emissions will also serve to practically eliminate the generated CAA regulated inorganic air pollutants (PM₁₀). By using the emissions estimating methodology outlined herein, calculation of air emissions for inclusion in CAA SIP permit applications may be performed in a quick, accurate, and cost effective manner.

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